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Cooperative Robot for Large Spaces Manufacturing

www.carlosproject.eu

ERF Workshop on Mobile Manipulation in Manufacturing,
Vienna, 13th March 2015

aimen TECHNOLOGY CENTRE · AALBORG UNIVERSITET · INESCPORTO · Deltamatic · ASTILLEROS JOSE VALIÑA, S.A. · Robotnik · C.A.T. progetti

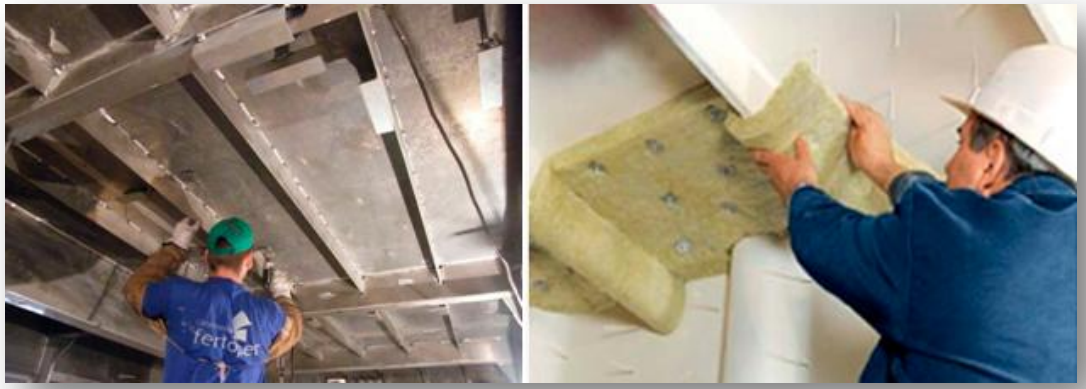
CARLoS, a cooperative mobile robot manipulator for stud welding and pre-outfitting marking

- A robot based on
  - Off-the-shelf components
  - ROS-based control software
  - Modular approach: platform-process-interaction
- Stud welding and marking capabilities in a real scenario
- A robot that is flexible and with quick RoI

1. **Application**
2. Navigation
3. Process
4. Cooperation

Application

- Pre-outfitting, one ship example
  - Over 2,000,000 pins welded
  - Over 10,000 hours of man power

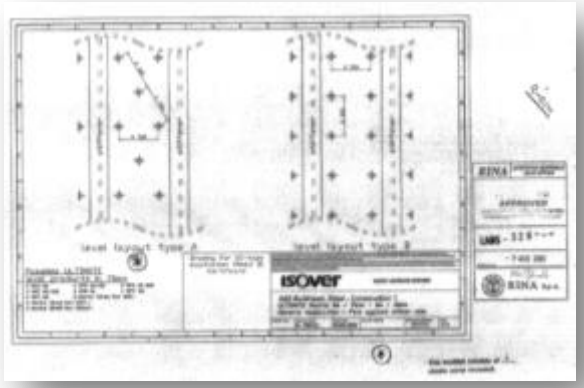


  - *No automated solution*

Application

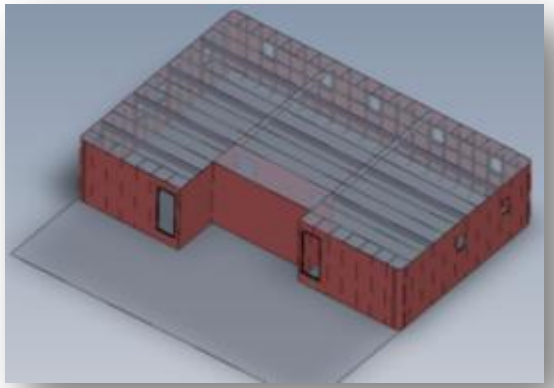
- Pre-outfitting
  - Stud welding and Marking
  - Specifications approved by classification societies

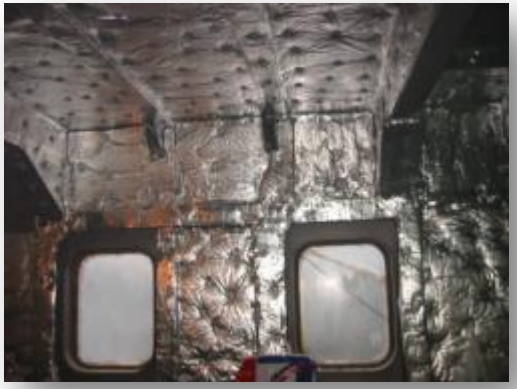
    - Stud length, diameter, material
    - Drawings of pins/studs distribution
    - Relative maximum distances, e.g.
      300 mm in height,
      207 mm in width
      100 mm at horizontal junction of blankets
      93 mm from stiffeners

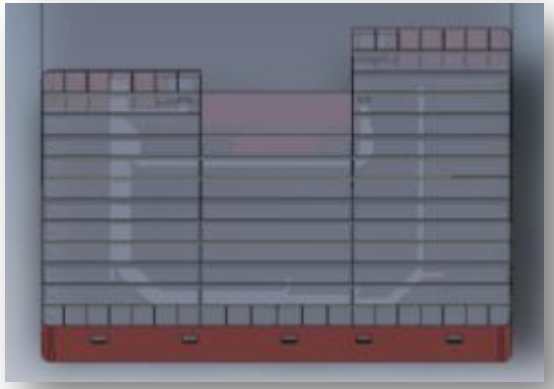


Application

- Scenario: VALIÑA's block with 3D CAD available
  - Maximum height: 2590 mm;
  - Stiffeners spacing: about 600 mm;

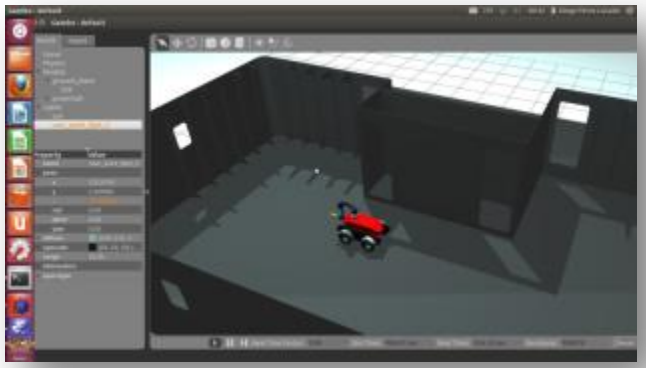




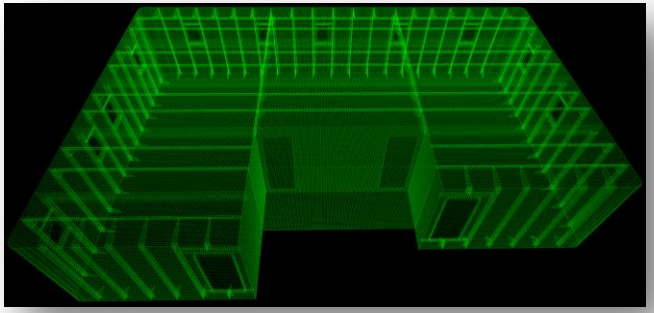


Application

- Robot functional requirements
  - Autonomous navigation
  - Autonomous stud welding and marking
  - Dependability
  - Cooperative
    - Supports human tasks (by marking)
    - Demand human cooperation to solve uncertainty

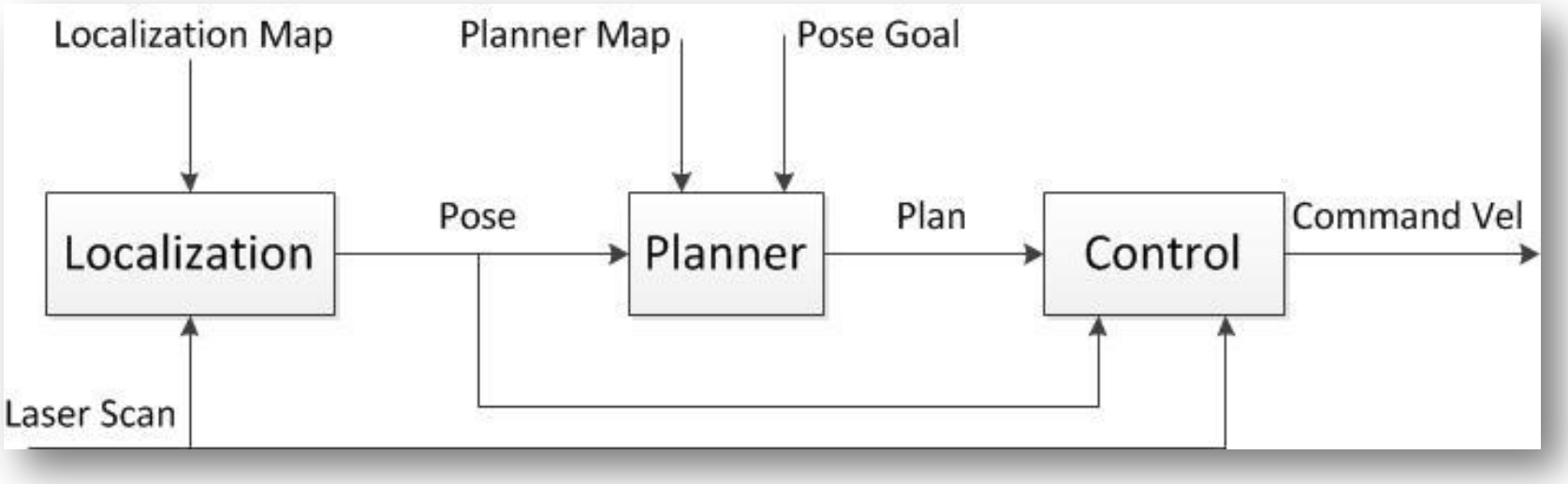


1. Application
2. **Navigation**
3. Process
4. Cooperation



Navigation control and planning

- Navigation Overview



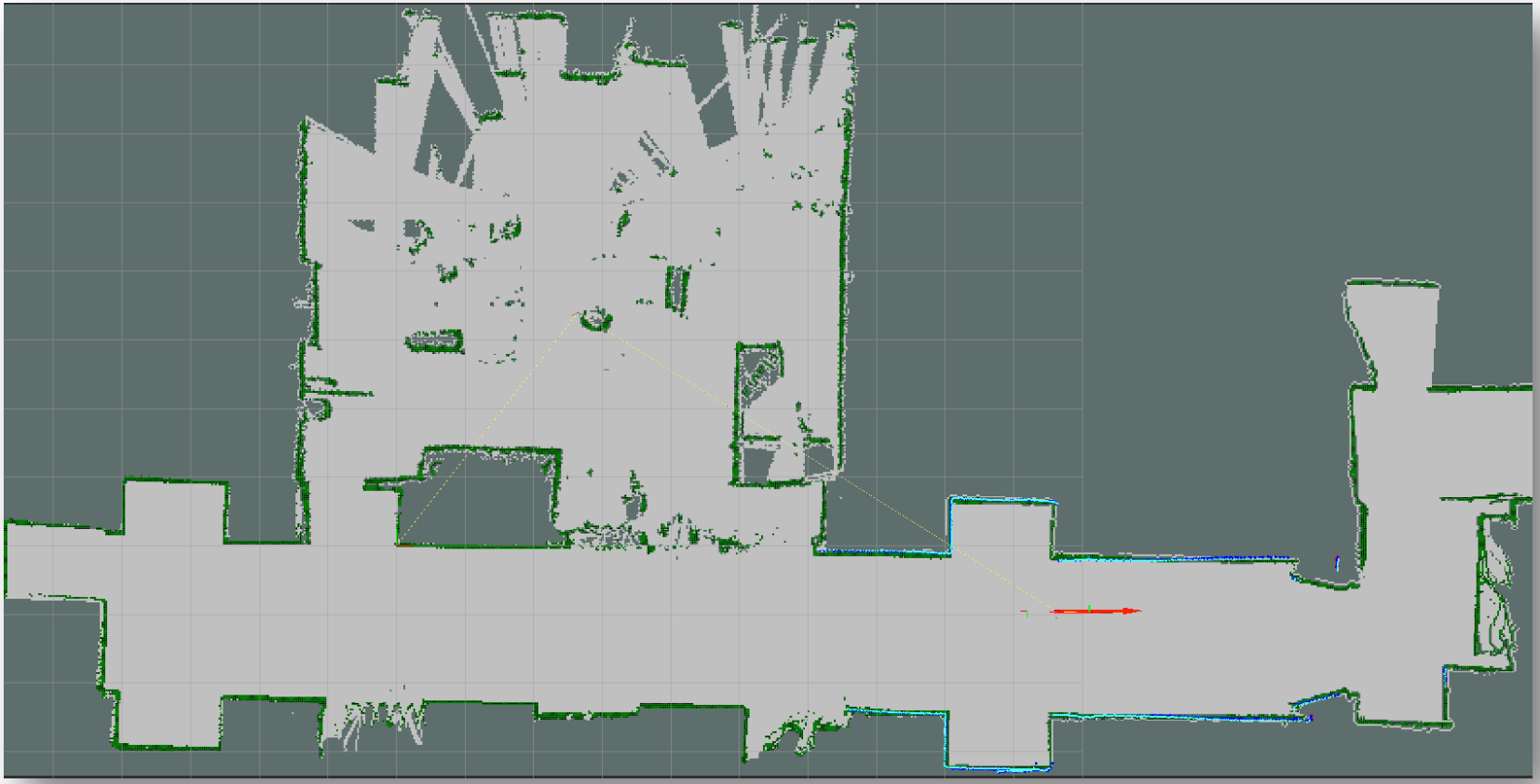
SLAM based on CAD generated maps

- SLAM based on CAD
  - Map update based on SLAM

Original map Updated map

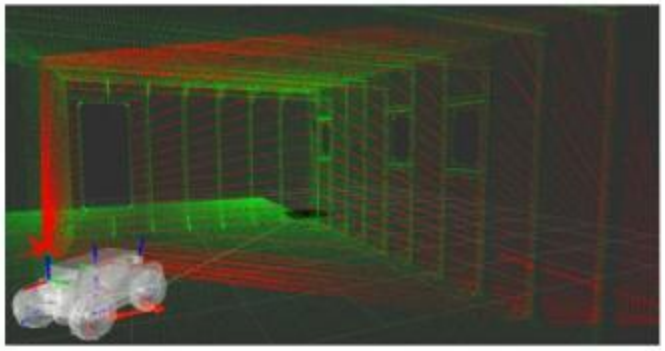
SLAM based on CAD generated maps

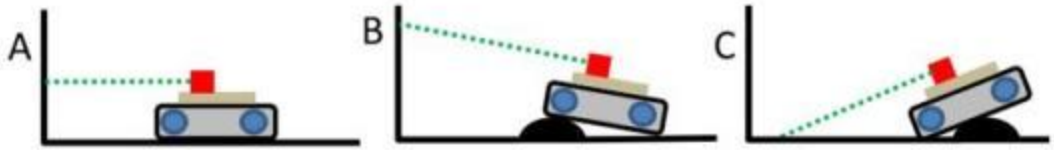
- Localization
  - CARLoS Dynamic Robot Localization (ICP based)



SLAM based on CAD generated maps

- Localization





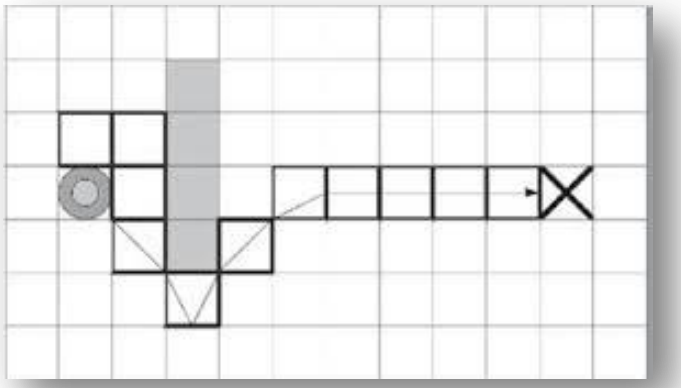
SLAM based on CAD generated maps

- Projection mapping

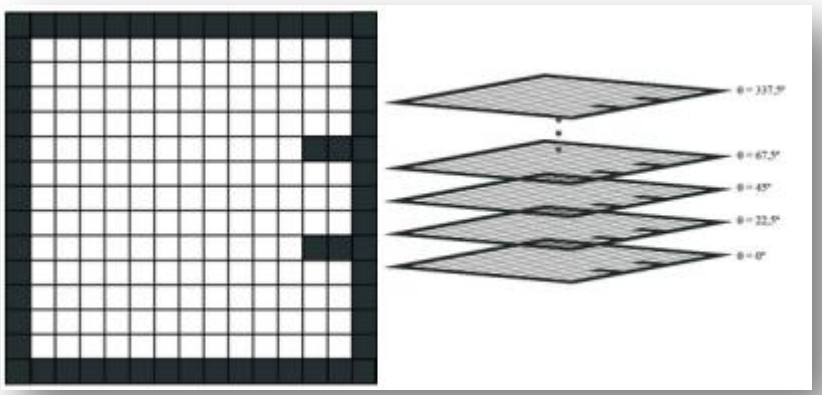
SLAM based on CAD generated maps

- Projection Mapping

- Path Planning:
  - A* extension: Orientation Enhaced Astar (OEA*)
  - Search space:

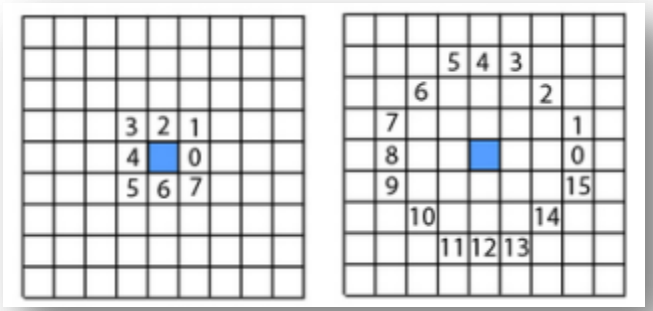


Original A* (2D)
(x, y)



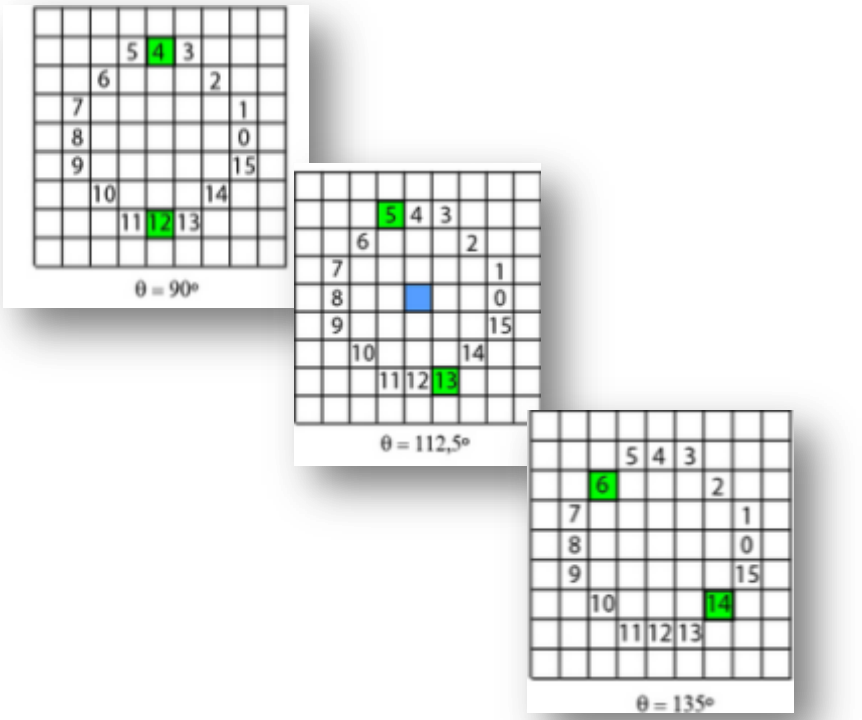
OEA* (3D)
(x, y, θ)

- Path Planning:
  - A* extension: Orientation Enhaced Astar (OEA*)
  - 16 neighbors -> Minimum turning radius

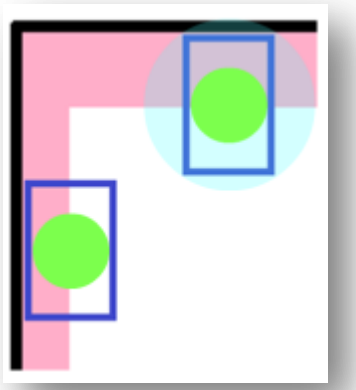


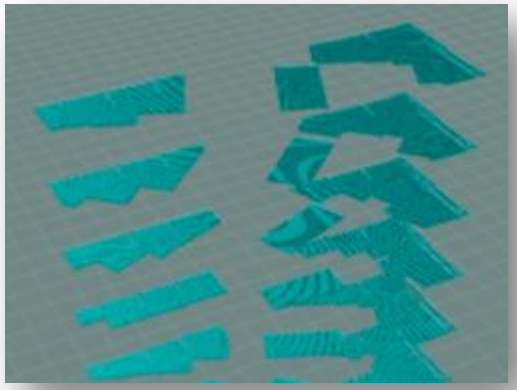
Original A*

OEA*

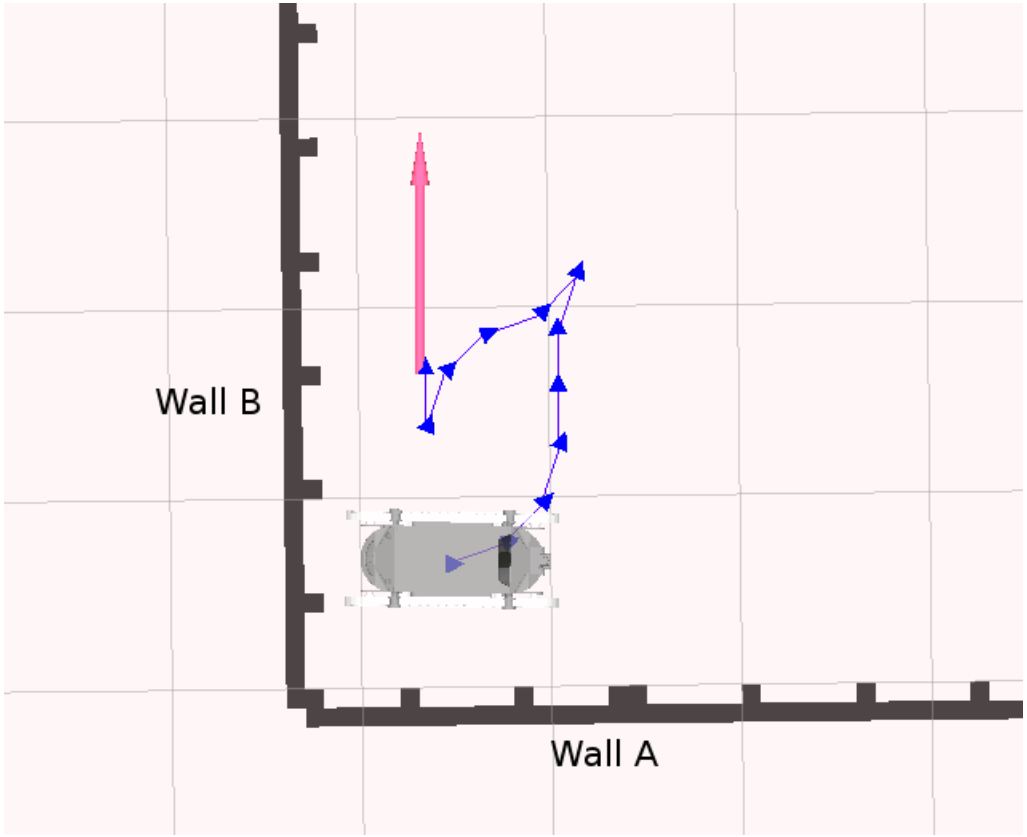


- Path Planning – Working Close to Walls
  - Oriented Obstacle inflation



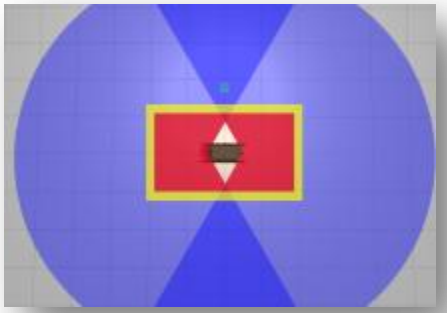


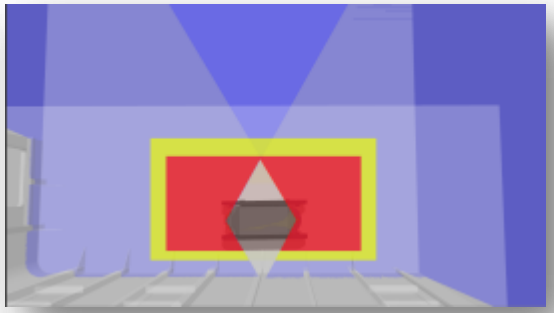
- Path Planning



Real time safety control

- Safety roadmap
  - Switchable field sets
  - Safe controllers from the arm – update area when stopped





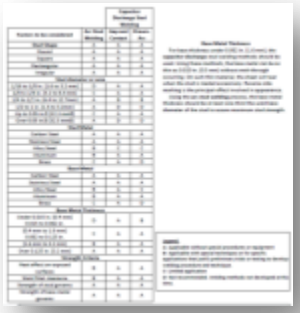
Initial laboratory trials

- Laboratory trials

1. Application
2. Navigation
3. **Process**
4. Cooperation

Process equipment

- Capacitor discharge stud welding

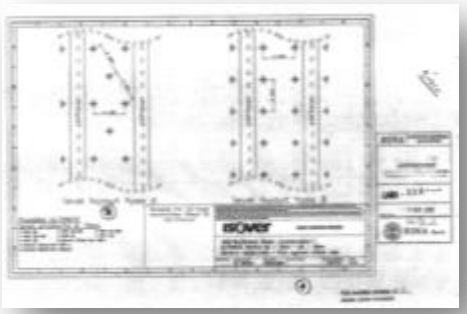


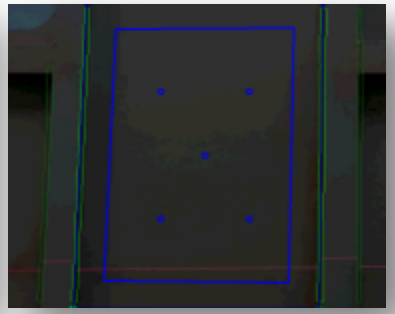
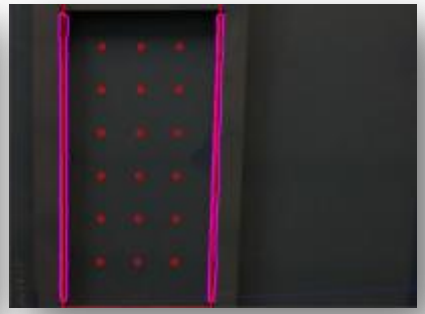
Welding tests with the robot

- Welding tests on samples of actual shipbuilding plates
  - Welding trials using the assembled manipulator
  - Weldability checks of welded pins

Sensing for local arm control

- Robot vision for stud positioning
  - Embedded platform, lightweight small camera, and structured light
  - Detection of stiffeners, identification of working area and estimation of 3D positions of the pins to weld, based on specifications of welding procedure

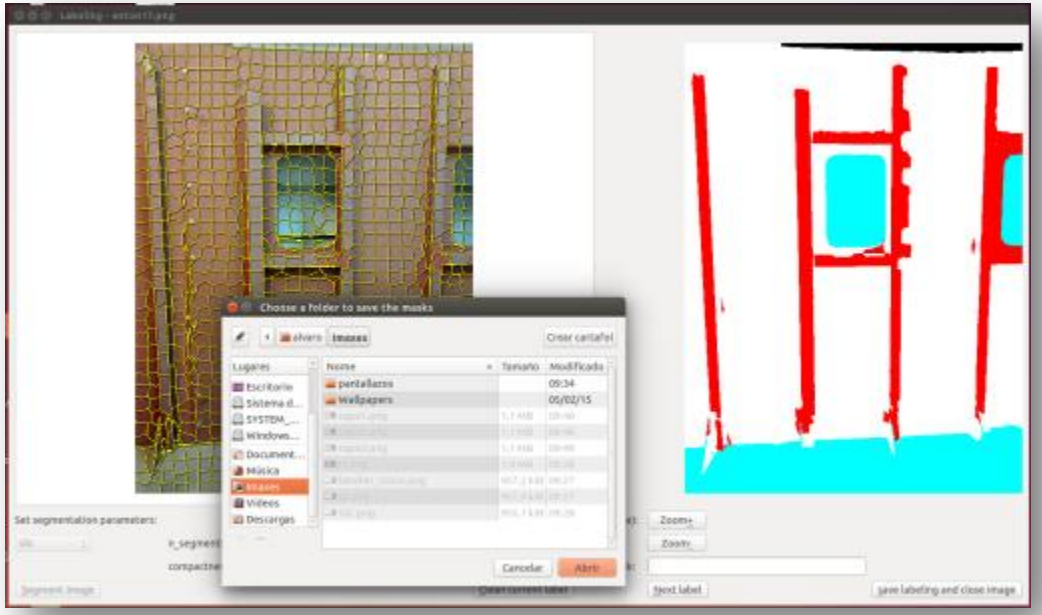


Direction	2*Standard Error (96% confidence interval) in [mm]
Normal	1.6
Transversal	4.7

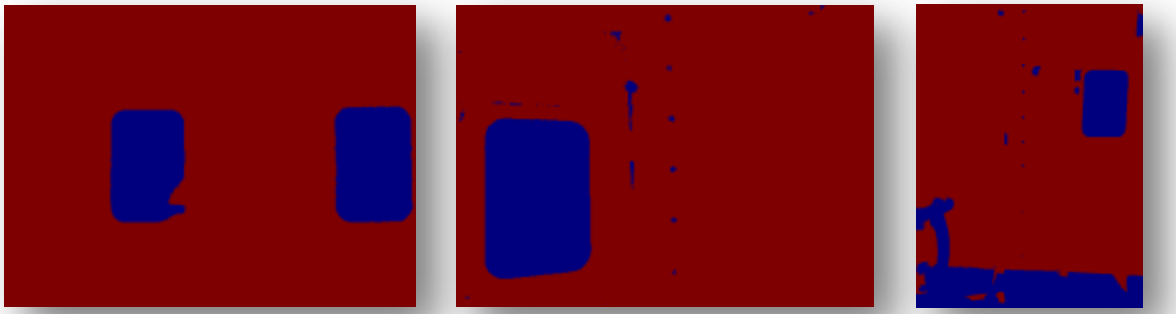
Sensing for local arm control

- Annotation-based segmentation
  - Intuitive wizard for quick semi-automatic annotation of scene based on superpixels



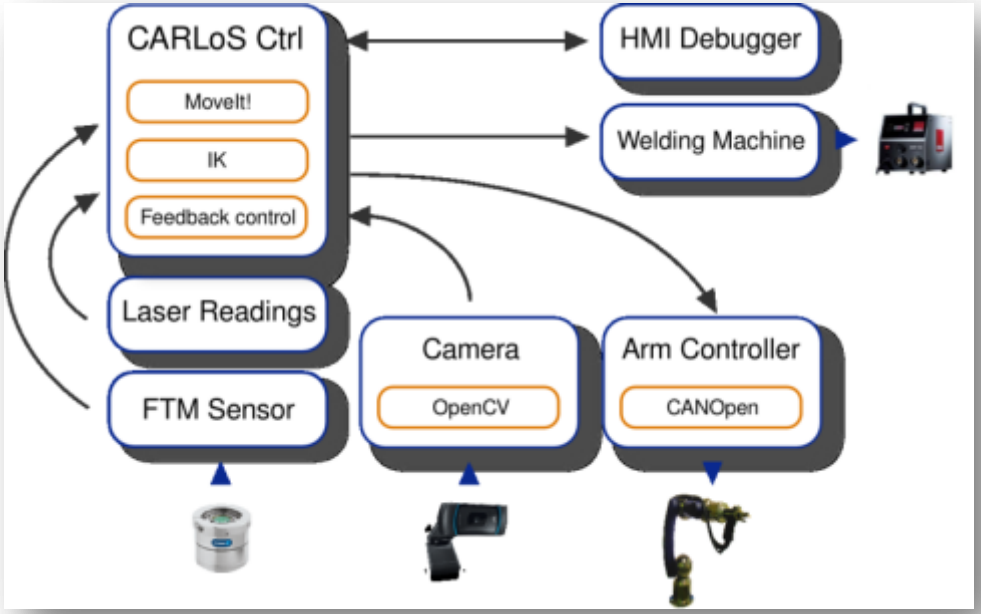
Sensing for local arm control

- Annotation-based segmentation
  - Intuitive wizard for quick semi-automatic annotation of scene based on superpixels
  - Robust segmentation adapted to current environment



T3.4: Arm and process control

- Arm control system based on MoveIt, OMPL, IKfast



Initial laboratory trials

- Laboratory trials

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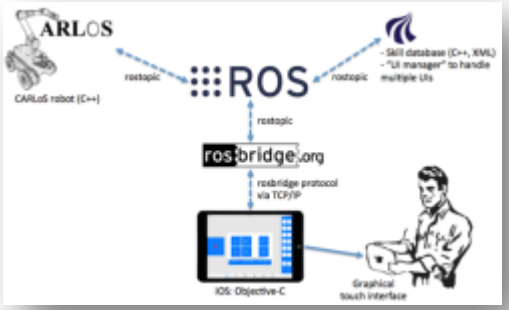
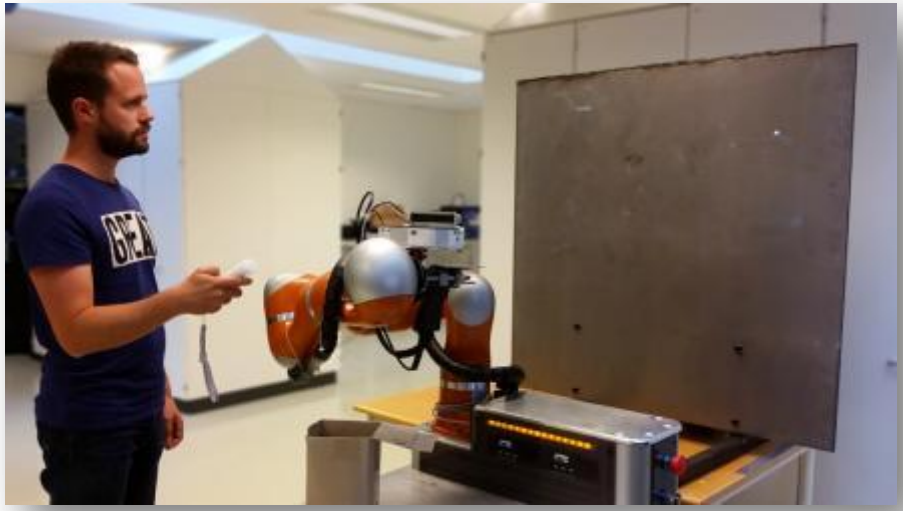


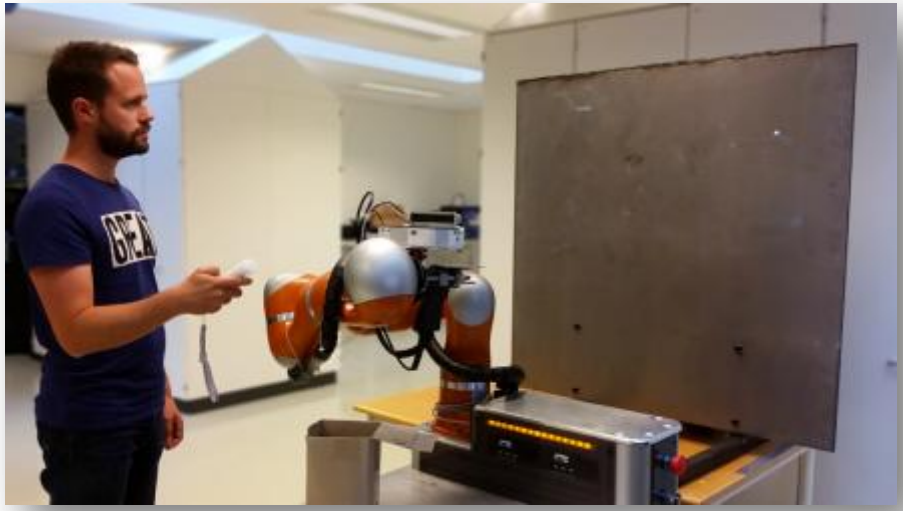
HRI approach

- Intuitive programming
  - Simplified HRI
  - Instruction in *object space*
  - COTS hardware to support this

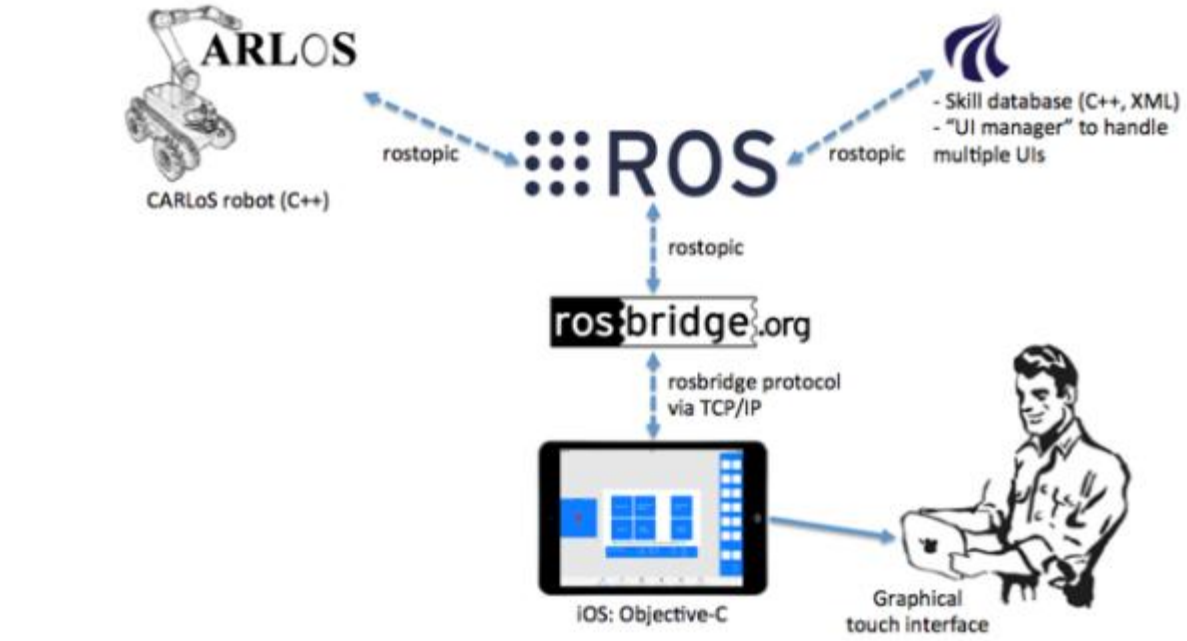


HRI approach

- Programming safety
  - How can we make sure the robot will execute what it has been taught?
  - We use *skills*



- HRI hardware and software architecture

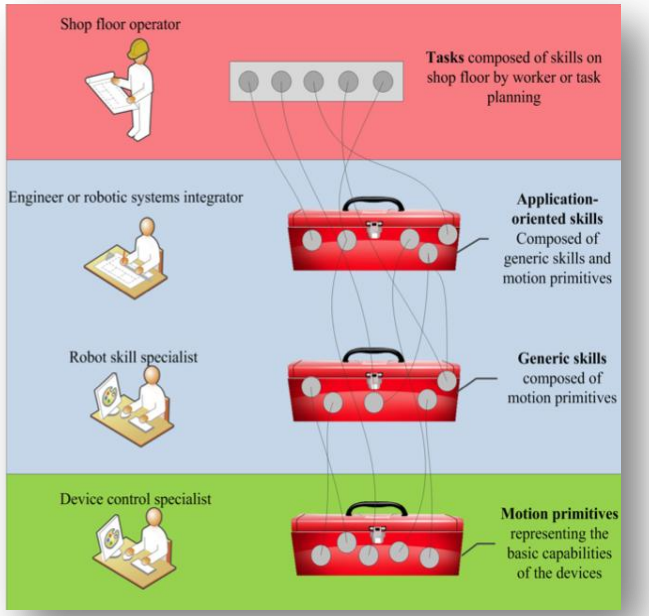




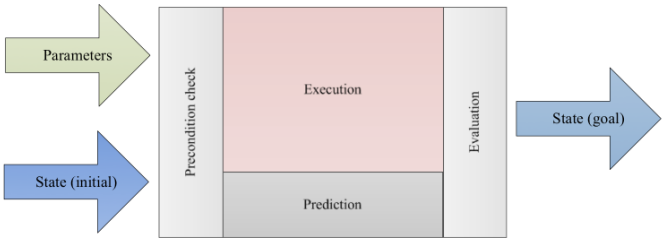


HRI approach

- Implementation layers of the robot skill terminology



- Skill model

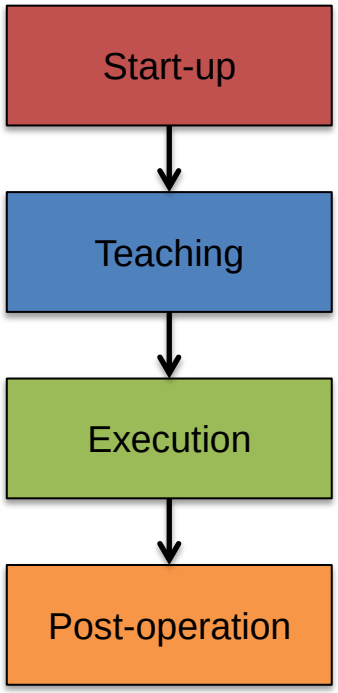


  - *Process parameters* (stud size, voltage, material)
  - *Pre-conditions* (studs available, safety conditions)
  - *Post-conditions* (stud is welded, quality check)

- Proposal: wizard-based instruction using robot skills
  → increases programming safety

HRI approach

- Task description decomposition and analysis
  - What phases will the operator go through?
    - Start-up, teaching, execution, post-operation (maintenance, shutdown)
  - What information feedback is needed?
    - Robot status,
      errors,
      available studs in magazine,
      instruction information

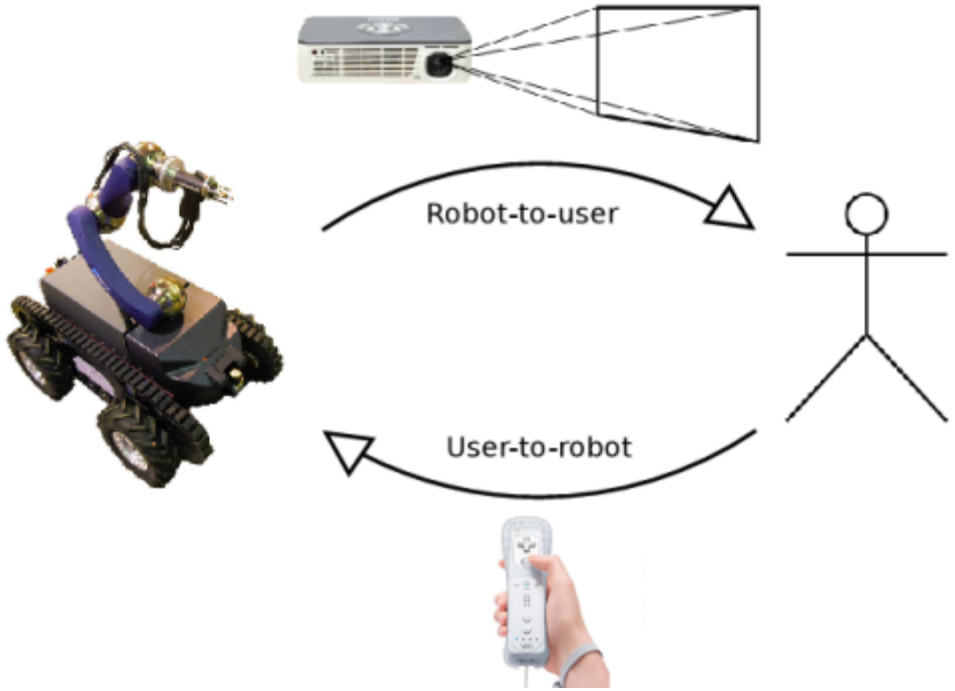


HRI approach

- Current implementation and test of interfaces
  - Wii remote plus (on-site)
  - iPad interface (on-site, remote)
  - Web interface (remote)
  - 3D sensor for wall detection and calibration
  - Projector for visual feedback

HRI approach

- During on-site teaching
  - The user should not be required to focus his attention on input/output devices such as a laptop or keyboard
  - Instead, he should be able to focus his attention on the space where the robot will carry out its task; the *object space.*



Initial Laboratory Trials

- Laboratory trials

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Thank you for your attention

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